

FIRST REPORT OF CUPRESSACEAN CONES IN THE EOCENE EYRE FORMATION OF SOUTH AUSTRALIA

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Conifer impressions are a very minor component in the various 'silcrete flora' assemblages found in the interior of South Australia. Previously, no fruiting bodies had been found, although numerous foliage species had been recognised. This note describes impressions of the first woody ovulate cones found, discovered in a small block of silicified sandstone near Lake Hart, west of Woomera. They are distinctive and do not appear to bear close affinity to any modern Australian species, but resemble cones of the African *Widdringtonia*.

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Besides *Athrotaxis*, the modern Australian flora contains three genera of cupressacean conifers: *Callitris*, *Actinostrobus* and *Diselma*. Recent morphological and molecular work by Gadek et al (2000) shows that the latter are closely related to an African genus *Widdringtonia*, within a monophyletic group, the subfamily Callitroideae, comprising all Southern Hemisphere cupressaceans except *Athrotaxis*.

Fossil conifers, including members of the Cupressaceae, are sparse in the Australian fossil record (Hill & Carpenter 1989). Many reported specimens have occurred as impressions in fine-grained sediments, with consequent difficulty in interpreting fine structure, but organic remains also occur, eg in Tasmania, and have yielded valuable material (ibid). This has more than doubled the number of genera in the Australasian region, with taxa that occur today in New Guinea, New Zealand and elsewhere, as well as several extinct genera (Hill & Brodribb 1999).

Plant impressions in silicified sandstone have been known from the Woomera area / Arcoona Plateau for many years (Chapman 1937), and as far as Stuart Creek to the north and Clayton Station on the Birdsville Track to the northeast. Most of the moulds are of angiosperm leaves (Rowett 1997), a few of which have been described (Chapman 1937; Greenwood et al 2001). Conifer vegetative shoots are a minor unobtrusive component, studied by Nunn (1964) and Offler (1969, 1984). In the 1970s localities were found yielding natural moulds of fruiting bodies, mostly of myrtaceous origin (Ambrose et

al 1979; Lange 1978). A few specimens referable to fruit of Proteaceae (*Banksia* sp.) and Casuarinaceae have been noted (Greenwood et al 2001; this writer, unpubl.) but, until now, no coniferous cones have been recognised, despite the widespread occurrence of vegetative shoots. Nunn (1964) recognised 21 different conifer morphotypes, some of which could be related to modern species from the Australasian region. She stressed the problems and uncertainties of identifying the species.

These plant fossil impressions occur in a number of isolated, discrete localities over an area of thousands of square kilometres, often in apparent channel deposits, eg at Nurrungar, Island Lagoon, near Woomera (pers. obs. 1969), in what has been regarded as Eyre Formation s.l. Their age has long been in dispute (Ambrose et al 1979; Callen & Lange 1986; Chapman 1937; Greenwood et al 1990; Wopfner et al 1974) but recent discoveries at Nelly Creek, Lake Eyre South, have at last related them to deposits datable by palynological studies to the middle Eocene (Alley et al 1996; Callen & Cowley 1995; Christophel et al 1992) within the Eyre Formation. Variations in the contained fossil floral assemblages suggest that the different localities probably have slightly different ages.

MATERIAL AND METHODS

In 1979 members of the Woomera Natural History Society discovered plant impressions near



FIGURE 1. Locality map, Lake Hart and other 'silcrete flora' localities in South Australia.

Lake Hart in the Woomera Prohibited Area (Fig. 1). Subsequently, L. Marsh and T. Nurenberg presented a slab of quartzite to the South Australian Museum (SAM P22732; Fig. 2) bearing the impressions of a few leaves and seven fruit-like bodies. Silicone rubber casts (Fig. 3) taken from these moulds disclosed fruits strongly reminiscent of *Callitris* ovulate cones. Closer examination, however, showed that, instead of the six subequal valve scales (2 triplets) seen in *Callitris*, these fruit had two unequal pairs of valves (Fig. 4). Re-examination of the collection of silcrete flora material in the Museum failed to uncover any further specimens; SAM P22732 is therefore unique.

Comparison was made with dried specimens in the South Australian State Herbarium and with trees growing at the Mount Lofty Botanic Gardens.

DESCRIPTION

Order CONIFERALES

Family CUPRESSACEAE Neger

Genus *Incertae sedis*

The cones are globose to ellipsoidal in shape, with a slightly conical distal apex. The ellipsoidal shape may be due to slight compression during burial, but the flattening is always the same relative to the smaller valve scales and symmetry of the cone, and compression is therefore an unlikely cause. Dimensions vary from about 17 mm diameter and a length of up to 22 mm for the globose forms, to 15–22 mm diameter x 20 mm in length for the ellipsoidal specimens. In apical view the pair of larger valves are at the ends of the apparent ellipse. The smaller, narrower, valves meet apically along a contact line of about 5 mm, thus separating the pair of larger valves (Fig. 4). Although apparently mature, the cones have a relatively smooth surface, with none of the roughness that characterises the opened cones of many *Callitris* species. However, one cone, at least, shows slight apically convergent ribs on the valves. This is reflected in an impression of what appears to be a decorticated cone (Fig. 3), having exposed ribs that have the same symmetry and relationships as the valves. None of the fruits has split to release its seeds, so the extent of the sutures separating the valves may not be fully expressed. Nevertheless, the sutures extend slightly more than halfway towards the base. The valves each have a near-apical, small (roughly 1 mm), circular to elliptical scar, arranged symmetrically on the fruit (Fig. 4). The origin or purpose of these scars is unclear, although they are in the same position as the 'spurs' on the valves of some species of *Callitris* (Baker & Smith 1910: 47) and species of *Papuacedrus*, *Widdringtonia* and *Tetraclinis* (pers. obs.; Hill & Carpenter 1989; McIver 2001). The base and attachment are seen in one specimen, showing a petiole expanding gradually to about 5 mm diameter at its junction with the fruit, where there is an expanded leaf scale below the smaller valve (Fig. 4). Another specimen seems to show a 7–8 mm diameter subcircular scar on the base, where the stem attached.

Comparisons

Initial comparisons were with species of *Callitris*. The obvious difference is in the number

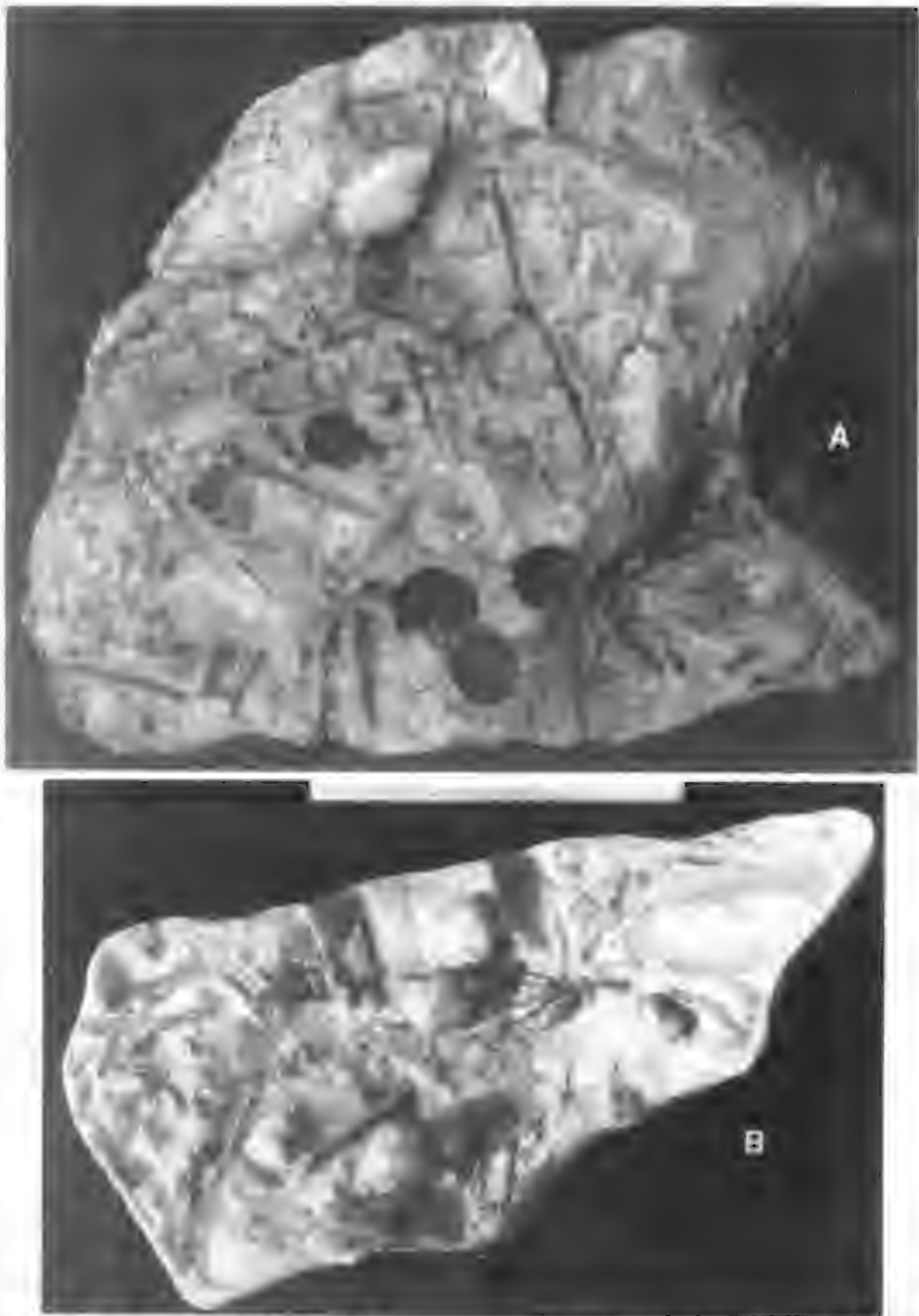


FIGURE 2. **A**, the fossil slab, SAM P 22732. **B**, positive cast of part of the slab, replicating the original appearance of the leaf litter at the time of burial. Scale in mm.

of valves in the cones, *Callitris* having three large valves alternating with three smaller ones, all ending acutely. Amongst living Australian conifers, there is only one species having two pairs of valves in the same decussate geometry as the fossils: *Diselma archeri* from Tasmania. However, its ovulate cones are tiny, barely larger in diameter than the shoots they terminate (pers. obs.). The living *Papuacedrus* from the island of

New Guinea also has two pairs of valves, but its cones too are small and conical (Hill & Carpenter 1989).

A passing note in Baker and Smith (1910) directed attention to several non-Australian genera. *Diselma* had once been synonymised with *Fitzroya* from Chile and Patagonia, just as *Callitris* had been joined with *Tetraclinis* from Mediterranean North Africa and *Widdringtonia*



FIGURE 3. Positive silicone rubber cast of the better fossil cones, showing 1, cone with apical view of sutures and valves with terminal scars; 2, cone with attached stem and basal leaf-scale; 3, cone with basal attachment scar; 4, a decorticated cone; 5, foliage fragment. Scale in mm.

spp. from southern Africa. I was not able to see fruits of *Fitzroya*, but am informed that they are nothing like the fossils (R. Hill, pers. comm., July 2002). Through the help of Ms H. Vonow at the South Australian Herbarium, I examined dry specimens of *Diselma archeri*, *Tetraclinis articulata*, *Widdringtonia cupressoides*, *W. whytei* and others and *Papuacedrus papuana*, and living *Widdringtonia* spp. in the Mount Lofty Botanic Gardens. There is an obvious similarity between

these species and the fossil cones in the number and symmetry of the valves. However, *Tetraclinis* can be removed from consideration on the basis of two characters; the spurs near the tips of its valves are quite enlarged, particularly on immature cones (there is obviously some allometric growth involved here), and the foliage structure is quite different from the fossil shoot associated with the cones. Offler (1969) indicates that *Papuacedrus* foliage is widely represented in her material, and



FIGURE 4. Detail of cones: silicone rubber cast showing 1, cone with apical view of sutures and valves with terminal scars, 2, cone with attached stem and basal leaf-scale, 3, cone with basal attachment scar, 4, foliage fragment.

it has been recognised in the Eyre Formation of the Poole Creek Palaeochannel near Lake Eyre South (Alley & Pledge 2000: 69). Fossil foliage has also been recorded from various Oligocene and Miocene sites in Tasmania (Hill & Brodribb 1999; Hill & Carpenter 1989). However, *Papuacedrus* differs considerably from the fossils in the tear-drop shape and small size of the cones, and in the presence of bract-like appendages halfway up each cone scale (Hill & Carpenter 1989).

There are two genera considered closely related to *Papuacedrus*, namely *Libocedrus* from New Zealand and New Caledonia, and fossil in Tasmania, and *Austrocedrus* from South America and also fossil in Tasmania (Hill & Carpenter 1989). They have ovulate cones of the same order of size as *Papuacedrus* (and therefore are much smaller than the Lake Hart fossils) but are similar in having a structure subapically on the abaxial surface of each cone scale: a spine in the case of *Libocedrus* and a minute tubercle in *Austrocedrus* (ibid). However, the cone scales of *Austrocedrus* are all apically acute with none truncated; therefore, that genus can probably be ruled out of contention.

The woody ovulate cones of the *Widdringtonia* spp. vary between species in both size and morphology. Like the fossils, they have two unequal pairs of valve scales, the upper pair having truncated apices that therefore meet along a contact of several millimetres. Of those examined, cones of *W. cupressoides* (Fig. 5) resemble the fossils most closely, although they tend to be smaller and have more prominent spurs on the valves, and the overall shape is more tulip-like, with a depressed base. Other species show a rougher, more rugose and warty or tuberculose surface on the valves than do the fossils, but this may be a reflection of the maturity of the fruit. The Lake Hart fossils differ markedly from the North American Cretaceous species *Widdringtonia americana* (McIver 2001), primarily in the development of a prominent umbo or boss on each valve scale in the latter species.

The vegetative shoot (Figs 3, 4) associated with the fossil cones is poorly preserved (the grain-size of the sediment approaching that of the smaller features), and cannot be guaranteed to relate to the cones. It seems to have the same square cross-section and short decussate, scale-like leaves as *Diselma archeri* (Clifford & Constantine 1980). This is unlike *Widdringtonia cupressoides*, which has shoots of rounder cross-section and longer decussate leaves. The leaves are apparently arranged in opposite pairs, as in *Libocedrus* and

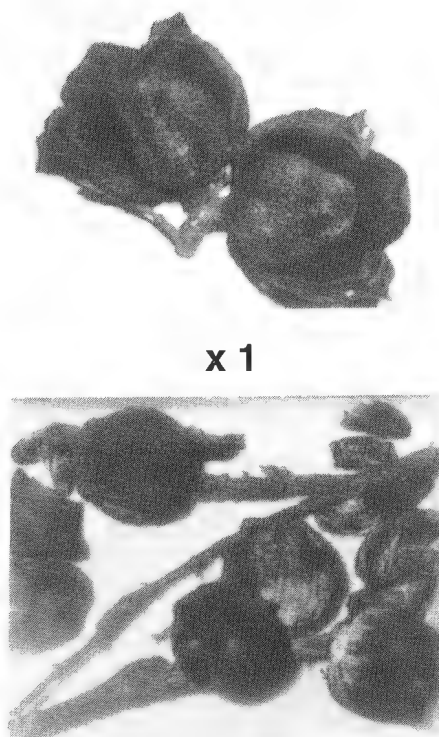


FIGURE 5. Female cones of *Widdringtonia cupressoides* (L.) Endlicher, specimens from the South Australian Herbarium collections.

Papuacedrus (Hill & Carpenter 1989). Unfortunately, no other specimens from this site are available to support or deny this association, and the locality has reportedly been stripped by commercial interests for decorative stone.

CONCLUSIONS

It is apparent that these impressions represent the fruiting bodies of a previously unknown Australian species of conifer, and it is suggested that this shows closest affinities with species of *Widdringtonia*, *Diselma* and *Papuacedrus*. Without corroborative evidence in the form of organically associated foliage and pollen, it is not possible to specify which taxon the cones represent; no identification is proposed, but it could be a new extinct genus. *Widdringtonia* today inhabits seasonally dry to semi-arid regions of southern Africa (Hill & Brodribb 1999), as do *Callitris* spp. Such an environment is implied (Alley et al 1996) for part of the Eyre Formation. In view of the fact that Offler (1969) found no

trace of either *Callitris* or *Actinostrobus* foliage in the 'silcrete flora' of the Woomera area, that no cones of *Callitris* have subsequently been found in the large collections made since her study, and that there have been only a few finds of fossil *Callitris* foliage in southeastern Australia (Hill & Brodribb 1999), it is suggested that these typical Australian genera evolved subsequently, possibly from a form like the fossil taxon described here.

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